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A Modular System for Situational Awareness

by Frederick S. Brundick

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A Modular System for Situational Awareness

Frederick S. Brundick
Information Science and Technology Directorate, ARL

Abstract

This report presents a modular collection of applications that provide situational awareness using standard combat net radios. Communications bandwidth is limited, while computers continue to become more powerful. Global positioning system (GPS) devices allow a unit to pinpoint its location and get the current time. In order to integrate this equipment, model-based battle command must be employed instead of traditional message-based techniques. A fully automated system is described that uses preplanned sequential objectives with information distribution technology (IDT) to determine the locations of friendly units.

Acknowledgments

I would like to thank George Hartwig and MAJ Scott Kothenbeutel for collecting the GPS data which are used in the demonstration described in this report. George also wrote the algorithm which converted the raw data into an objective sequence. Cynthia Sarafidis developed and tested the module which performs combat identification.

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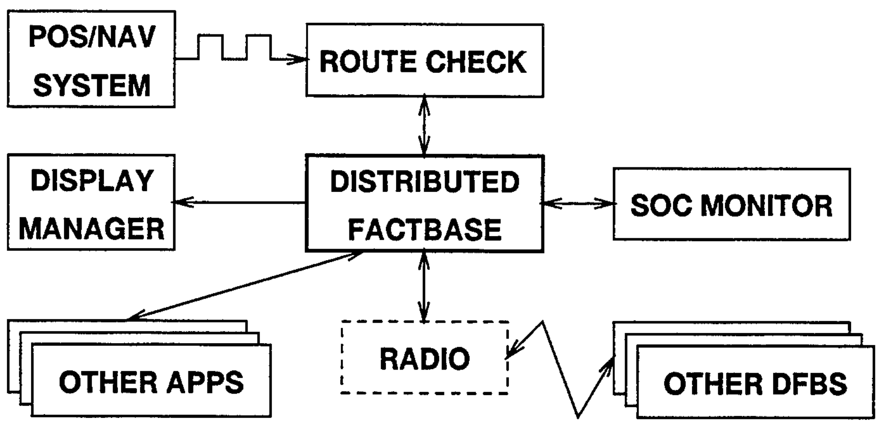
Executive Summary

This report describes how a model-based, computationally intensive paradigm—rather than a message-based, communications-intensive one—may be employed to provide true situational awareness (SA) across the battlefield. For SA to exist on the modern battlefield, information must be collected, correctly routed, and assimilated. This must occur automatically and without overburdening either the soldiers or the limited communication links existing at the low echelons that are the source of information and the executors of operations. In current systems, the tendency is to supply *positional* awareness and not *situational* awareness. JSTARS images, as seen in Desert Storm press releases, show where vehicles are, but do not indicate how well the mission is progressing. Only when the analyst combines current positional data with the maneuver plan, associates units with the vehicles, and compares their locations to where they are expected to be is true SA obtained.

The SA model was designed with component reuse and substitution as major criteria. A block diagram of the modules is shown below. The goal of this model is to show—both as a simulation and in actual field tests—that SA may be achieved with minimal radio traffic by using preplanned sequential objectives.



Components of SA Model.

Each module is a separate application and has one or two primary functions.

Distributed FactBase (DFB) – Contains a database describing the current situation, plans, and reference data; provides interprocess communication between the modules; sends and receives data to/from other DFBs over combat net radios.

Position/Navigation (Pos/Nav) System – Periodically provides time and location of current unit.

Route Check – Given the time, computes the planned location of all units with sequential objectives; compares the known position of the current unit with its planned location.

Shape of Certainty (SOC) Monitor – Notified by the DFB when current unit is not where it is expected to be as defined by its sequential objectives and tolerance.

Display Manager – Graphically shows sequences and planned locations of all units and actual position of current unit.

The DFB contains a set of rules that tells it when to communicate with other units (actually their DFBs) and what data to send. Other rules notify applications (such as SOC Monitor) when certain actions occur, e.g., when a unit moves. By having all the applications store data in the DFB, it is much easier to replace one application with another. The programs need to know how to interface with the DFB, not with each other. A unit will be running several applications connected to its DFB, not just the ones described previously for SA. The SA programs plug into the existing DFB and communication systems.

At the beginning of an exercise, every unit starts its own DFB and other applications. The applications connect to the DFB and extract whatever initial data they need; for example, Route Check gets all sequential objectives. At fixed time intervals, the following steps occur:

1. Pos/Nav System sends the unit's current position and the time to Route Check.
2. Route Check computes the planned location of every desired unit and stores the results in the DFB.
3. Route Check determines if the current position is within the allowable area of the unit's planned location.
4. Route Check stores the actual position and the result of step 3 in the DFB.
5. The DFB notifies the Display Manager that certain units have moved so it may update its map.
6. If the unit is not where it is expected to be, the DFB alerts the SOC Monitor application. Other DFBs may be notified by radio.
7. The process repeats.

The modules and steps described previously demonstrate that SA may be provided with minimal radio traffic by using preplanned sequential objectives and model-based battle command.

1. Introduction

Information distribution technology (IDT) is a long-term research project of the Communications and Network Division of the Information Science and Technology Directorate (IS&TD) of the U.S. Army Research Laboratory (ARL). The goal of IDT is to combine the power of the modern digital computer with the tenets of model-based battle command (Chamberlain 1990). By devising a way of exchanging tactical information over low bandwidth channels (i.e., combat net radios), sophisticated command and control tools may be deployed to lower echelons.

This report describes a collection of computer applications that use IDT to provide situational awareness (SA). Rather than adopting a monolithic approach, a modular approach was used, where each module is intended to perform one or two operations. The applications exchange data with each other through the Distributed FactBase (DFB). This decouples the modules and allows them to be replaced with other components. For example, a demonstration version could use a Position/Navigation (Pos/Nav) System program to supply simulated time and position data, while a field test version could use actual positioning hardware. Other applications may access the DFB and retrieve data instead of duplicating the computations; e.g., a combat identification program could retrieve the expected location of units to identify an unknown vehicle.

2. Components of the SA Model

2.1 Pos/Nav System

The Pos/Nav System drives this model by providing the time and the unit's location at fixed time intervals. It consists of four subsystems:

1. GPS Unit – A global positioning system (GPS) or similar piece of hardware is the primary means for determining a unit's location and the current time.

2. Inertial System – A secondary piece of hardware that estimates the unit's location based on onboard sensors.

3. Dead Reckoning Software (S/W) – Estimates the location by extrapolating from the last known position(s). It supplies the time when other hardware fails.

4. Position/Time S/W – Manages the hardware subsystems and outputs the time and location to the Route Check application.

A GPS alone is not sufficient to guarantee a position fix. It may not be able to lock in on enough satellites, perhaps because of obstructions. When that happens, other hardware is used to estimate the unit's location by monitoring the unit's heading and speed since the last GPS update. Such a device has been built by the U.S. Army Topographic Engineering Center

(TEC). Their low cost navigator (LCN) combines an Army-standard precise lightweight GPS receiver (PLGR) with an odometer speed sensor, a digital compass, and a microprocessor to compute the unit's position (Michael 1996). The LCN is essentially subsystems 1 and 2 from the previous list.* The dead reckoning software is not expected to be very accurate, since it assumes the unit has been traveling in a straight line since its last known speed and heading. However, dead reckoning may be used to predict the movement of enemy units.

The Position/Time S/W controls the Pos/Nav System. It outputs the unit's position regardless of how it was obtained. If for some reason it cannot provide a position, it must supply Route Check with the time.

2.2 Route Check

The Route Check application is the component that deals with the sequential objectives. It extracts all primary and alternate objective sequences from the DFB for the friendly units that the user wants to track. When it gets the time from the Pos/Nav System, it computes the planned location of each unit and stores the information in the DFB. It then compares the known position of the current unit (also obtained from the Pos/Nav System) with its planned location, subject to the allowable error tolerance, called the shape of certainty (SOC). The model presented here uses SOCs that are circular.† The status of the unit—whether or not it is within its expected area—is also stored in the DFB.

2.3 Distributed FactBase

The Distributed FactBase is the hub about which all data moves (except for the Pos/Nav System ⇒ Route Check interface). It is an active database that provides both interprocess communications and connectivity to other DFBs (Hartwig 1991). Applications running on the same node connect to the DFB on that node. They each register **triggers** (Cohen 1989), or active queries, to monitor updates made to the DFB. When the desired conditions are met, the application is notified by the DFB.

Similar active queries called **data distribution rules** are loaded into the DFB. These rules tell the DFB to send information to other nodes when certain conditions are met. They are part of the unit's standing operating procedures (SOPs).

The DFB trigger mechanism allows the modules to be written with a common data interface instead of requiring them to know how to directly exchange data with each other. This loose coupling permits different applications to be used. Once the IDT Application Programming Interface (API) has been incorporated into a program, it may connect to a DFB, perform updates and queries, register and process triggers, etc. If the programs exchanged data directly, new interfaces would need to be written every time one of the modules was replaced with a different program.

*A true inertial system is cost prohibitive at this time.

†For details on the construction and implementation of SOCs and sequential objectives, see Hartwig et al (1996).

The DFB contains the sequential objectives as part of the operational orders (OPORD). Each friendly unit would have a primary sequence, while alternate sequences would provide for contingencies like a bridge being out.

2.4 Display Manager

The Display Manager is a graphical user interface. It retrieves the expected and actual locations from the DFB and plots them on a map. For test purposes, the Display Manager should be capable of drawing the tolerance area around each expected location. A field version, which could be a complete command and control system, would show the locations along with other battlefield information. It may also be used in the planning phase to construct the objective sequences and other OPORD details.

2.5 SOC Monitor

The SOC Monitor is another application which may vary in sophistication. As a proof of concept, a minimal version would indicate when the current unit is not within its expected tolerance area. A more advanced version could perform a variety of actions depending on the severity of the problem, such as:

- notifying other units via the DFB,
- allowing the user to switch to an alternate sequence,
- starting a route planning application to make changes.

2.6 Other Applications

Other applications may be connected to this DFB. They may be entirely separate from the SA modules described previously, or they could use the SA data to perform other tasks. For example, a combat identification (ID) application could use the expected locations stored in the DFB to infer if an observed vehicle is friendly or not. Otherwise, it would need to extract the current routes and perform the same SOC computations as Route Check.

2.7 Other DFBs

In the IDT model, units communicate with each other by sending database updates to their DFBs. Messages for SA would include reports that a unit will not reach its next objective in the allotted time, changes to current sequences, new sequences, and the actual location of the unit.

3. Operation of the SA Model

3.1 Overview

The operation of the model is divided into three phases. Pre-Initialization consists of steps that are performed once. This includes, but is not limited to, defining the units, planning the primary and alternate objective sequences, writing the OPORD, and storing the data in the DFBs. If a simulation is going to be run, time and location data should be generated for the Pos/Nav System. Initialization steps are performed at the beginning of the exercise. The DFB process and other applications are started; then the applications connect to the DFB and retrieve the sequences and other static data they require. The Execution phase is the bulk of the model and will be explained in more detail.

3.2 Execution Phase

3.2.1 Discussion

This discussion will use actual data from a demonstration. It consists of two units: Alpha, the unit that belongs to this node, and Bravo, a second unit.

The Pos/Nav System periodically sends the current time and the unit's location to Route Check. A sample Pos/Nav System for unit Alpha is shown in figure 1. The demonstration is stopped at 1 minute and 47 seconds into the mission. The unit is located at the Universal Translator Mercator (UTM) coordinates* 407934,4368511 and at an altitude of 0 meters. It is following the sequence "amber,"† and the demo is running in real time.

The Route Check program receives the time and computes where each unit is expected to be. The input data at time 1:47 and results are shown in table 1. Bravo is performing the same calculations; however, it knows its actual location but not Alpha's. Alpha is 33.1 meters from the center of its SOC, well within the SOC radius of 100 meters.

Table 1. Route Check Calculations

		SOC		Actual			
Unit	Segment	Easting	Northing	Easting	Northing	Radius	Distance
Alpha	3 of 12	407920	4368541	407934	4368511	100	33.1
Bravo	3 of 10	407690	4368531	n/a	n/a	80	n/a

Route Check stores the two computed SOCs in the DFB so that other modules may retrieve the values. It also stores the actual location as provided by the Pos/Nav System,

*The program may use latitude and longitude data instead.

†Every sequence has a unique name.

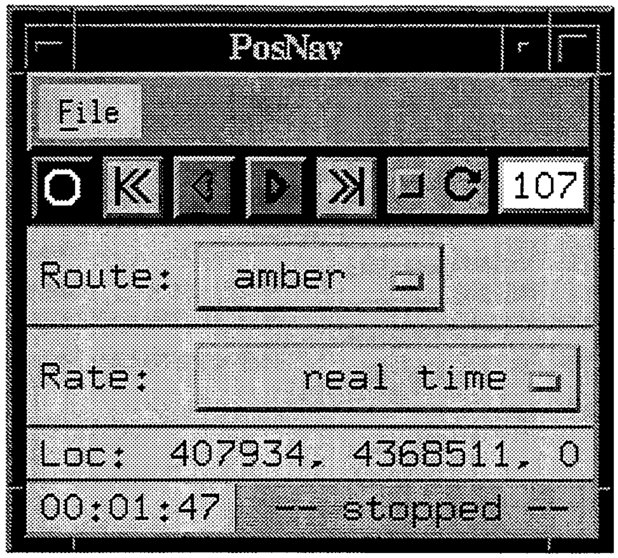


Figure 2. Sample Pos/Nav Application.

along with a flag indicating Alpha is within its SOC. Each time the Pos/Nav System sends GPS data to Route Check, the SOCs are computed and everything is updated in the DFB. Notice that no human intervention is required. Simulated GPS data is fed directly to Route Check, which does all the analysis and stores the results in the DFB.

3.2.2 Course Deviations

It is important to show that other applications may be notified when the unit is outside of its SOC. The SOC Monitor program registers a trigger for this purpose. When Route Check stores a location with the "out of SOC" flag set, the trigger fires. The SOC Monitor retrieves the details from the DFB and prints them.

A distribution rule causes the unit's actual location to be broadcast at the same time. In this example, when Alpha goes outside of its SOC, the position information is sent to Bravo and stored in its DFB. A trigger on Bravo alerts its copy of SOC Monitor, and a similar message about Alpha's position appears on Bravo's display.

3.2.3 Display Manager

A graphical display is required to show that everything is working properly. The sample programs have the ability to print all computations for verification, but tables of numbers are not very intuitive. The Display Manager created for this exercise is shown in figure 3. On startup, the Display Manager connects to the DFB and extracts all the objective sequences. Each active sequence is drawn, using one color for the current unit and another color for all other units.

Triggers are registered to notify Display Manager when the following events occur:

- an actual unit location is stored or updated in the DFB,
- a SOC is stored or updated in the DFB,
- a unit switches to an alternate sequence.

In the example, Alpha unit is following the outside sequence (the lighter line). Its actual location is inside the SOC, just southeast of the center. Bravo unit is on the inner, darker sequence. Its SOC is smaller, and the actual location of the unit is not known by Alpha. If Bravo were to stray outside of its SOC, its position would be shown on the map briefly.

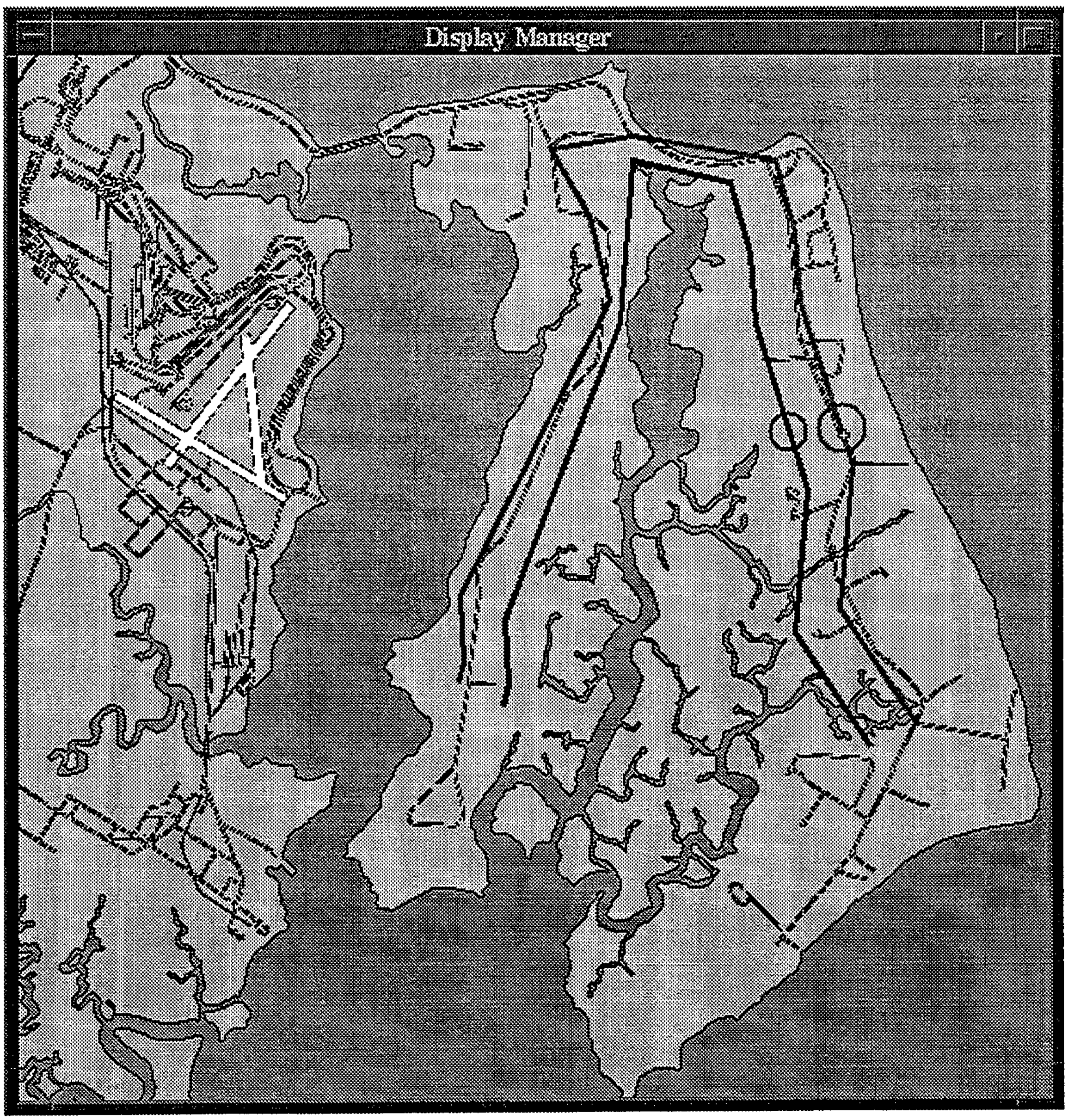


Figure 2. Sample Display Manager Application.

4. Future Developments

New features are continually being added to the Display Manager program. By displaying the sequences, SOCs, and actual unit locations on the map, it is easy to see where everyone is and where they are headed. To show that the situation may be obtained, the user may put the sample Display Manager into an identification mode. He may click on any object on the screen and get a summary of information from the DFB. Table 2 shows the information about Alpha's SOC at time 1:47.

Table 2. Information About Alpha

SOC for Alpha Unit:		
east	=	407920
north	=	4368541
radius	=	100
actual unit location:		
east	=	407934
north	=	4368511
unit is in its SOC		

Another mode demonstrates how sequential objectives and SOCs may provide combat ID. The user clicks on the map to place his location and then clicks a second time to show his line of sight. The program determines if the line intersects any SOCs, indicating that the user is seeing a friendly unit. In an actual system, the user's location would come from his GPS, and the bearing would be taken from a weapon sight or range finder.

The Pos/Nav System has been modified to allow a multinode simulation to be run in real time. It interfaces with the DFB, mainly to have access to the unit's radio. When any unit's Pos/Nav System is started, it stores the time rate, index of the initial data point, and the clock time when the simulation should start in the DFB. A distribution rule broadcasts the fact as an out-of-band message (i.e., it is not part of the simulation) to all the other nodes. The Pos/Nav System on each of them is notified by a trigger and automatically starts at the desired time with the proper settings. Likewise, any unit may broadcast a "stop" message.

5. Conclusions

The rules and triggers described demonstrate how the various modules work together to provide SA with limited bandwidth. The scenario in the example runs for 8 minutes and 44 seconds, while Alpha unit travels almost 7 kilometers. If Alpha reported its position every 100 meters, a typical value for SA proposals, it would send 70 messages. Assuming a constant speed (which turns out to be a reasonable 30 miles per hour), that is a message every $7\frac{1}{2}$ seconds.

Every unit on the same frequency would be reporting its position, leading to contention for the limited bandwidth. Add in the fact that other messages are being sent, such as spot reports, and the radios quickly become congested. If everything works properly, everyone's position will be known to everyone else, but nothing about their *situation* has been transmitted.

In contrast, the use of preplanned sequential objectives will require zero message traffic if a unit adheres to its plan. If the unit has not sent any other messages, it may notify other units that it is still operational either periodically, when it crosses a phase line, or when it reaches a waypoint. During periods of communications blackouts, either unintentional or radio silence, the models will compute where everyone is expected to be and where they are going. Not only is message traffic greatly reduced, but SA is available even when communications are disrupted.

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List of Abbreviations

API	Application Programming Interface
ARL	Army Research Laboratory
DFB	Distributed FactBase
GPS	Global Positioning System
ID	Identification
IDT	Information Distribution Technology
JSTARS	Joint Surveillance Target Attack Radar System
LCN	Low Cost Navigator
OPORD	Operational Orders
PLGR	Precise Lightweight GPS Receiver
Pos/Nav	Position/Navigation
S/W	Software
SA	Situational Awareness
SOC	Shape of Certainty
SOP	Standing Operating Procedure
TEC	Topographic Engineering Center
UTM	Universal Translator Mercator

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